

UNCLASSIFIED

AD 4 4 4 9 6 2

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.



ELECTRONICS LABORATORY, Syracuse, New York

SEMIANNUAL REPORT

For the Period January 1, 1964 - June 30, 1964

AROMATIC ORGANIC LASER DEVELOPMENT

by

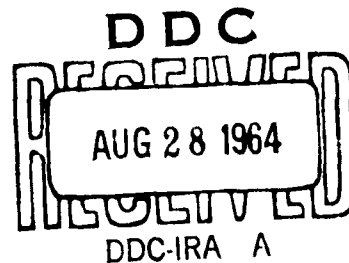
WR Mallory
RA Shirk
DL Stockman

This research is part of PROJECT DEFENDER under the joint sponsorship of the Advanced Research Projects Agency, the Office of Naval Research and the Department of Defense.

Contract No. NONR 4135 (00)
From Office of Naval Research
Project Code 3730
Order No. 306-62

Prepared for

Office of Naval Research
Department of the Navy
Washington 25, D.C.



Prepared by

Electronics Laboratory
General Electric Company
Building 3
Electronics Park
Syracuse, New York

Submitted by

Heavy Military
Electronics Department
General Electric Company
Building 3, Room 4
Court Street Plant
Syracuse, New York

444932

CATALOGED BY DDC

AS 11-110.

Semiannual Report

AROMATIC ORGANIC LASER DEVELOPMENT

Contract No. NONR 413500
from the
Office of Naval Research

Sponsored by

Advanced Research Projects Agency
Project Code 3730
Order No. 306-62

Contract Initiation Date: 1 April 1963
Contract Termination Date: 31 March 1965
Amount of Contract: \$90,314.00

Prepared by

Electronics Laboratory
General Electric Company
Electronics Park
Syracuse, New York
992-GH-921

Submitted by

Heavy Military Electronics Dept.
General Electric Company
Bldg. 3, Room 4
Court Street
Syracuse, New York

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
I	INTRODUCTION AND SUMMARY.....	1
II	MATERIALS SELECTION AND PREPARATION.....	2
	A. Spectroscopic Measurements.....	2
	B. Polymerization Studies.....	2
	C. Optical Properties of Polymers.....	3
III	DEVICE DEVELOPMENT.....	6
IV	BIBLIOGRAPHY.....	8
V	DISTRIBUTION LIST.....	9

I. INTRODUCTION AND SUMMARY

The purpose of this program has been to produce coherent stimulated emission in the blue-green region in a purely organic dopant-host system. Towards this end, the experimental program of the last six months has been concerned primarily with the study of the optical properties of the polymers to be employed and on the development of a high peak power pumping source. Progress has been made in both of these areas.

II. MATERIALS SELECTION AND PREPARATION

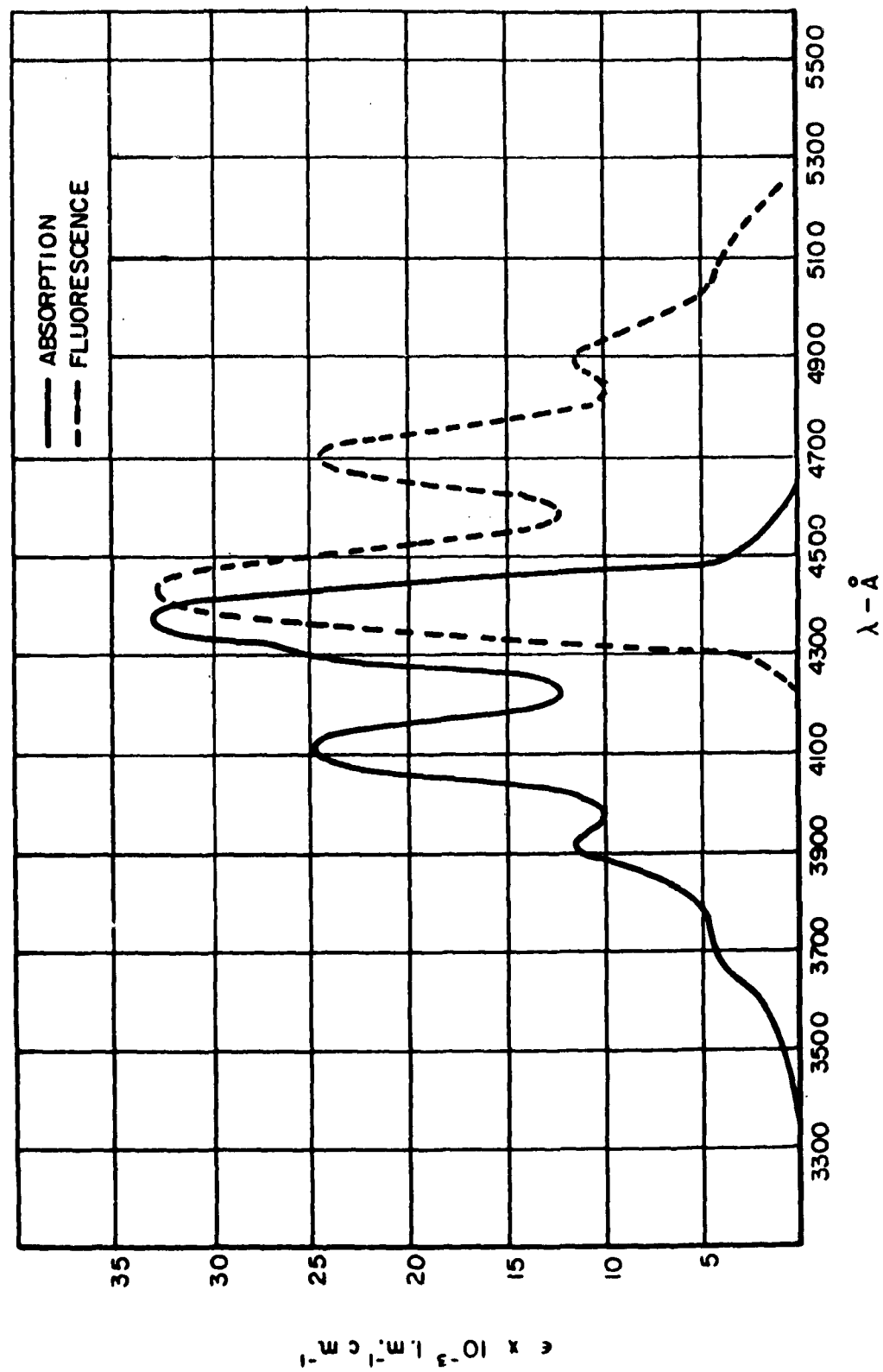
A. Spectroscopic Measurements

The previous semiannual report noted that two molecules had been found with suitable spectroscopic properties. The two compounds are perylene and 9-aminoacridine. The routine spectroscopic features of these compounds were presented in the previous report. We have made some additional spectroscopic measurements. From the absorption and emission data for perylene, shown in Figure 1, the terminal-ground state splitting is measured by the energy difference between the 4710 Å fluorescence peak and the crossover (the 0-0 transition) point: between the absorption and emission spectrum at 4445 Å. The energy separation is 1266 cm^{-1} . The long wavelength absorption ($>4445\text{ Å}$) of the perylene is due to transitions of the upper vibrational-rotational levels of the ground electronic state to the lowest vibrational-rotational level of the excited state. The population arises from simple Boltzmann statistics. Owing to the near perfect mirror symmetry of the absorption and fluorescence spectrum, it would be anticipated that absorption at the 4710 Å terminal state would have the same cross section as the 4100 Å peak.

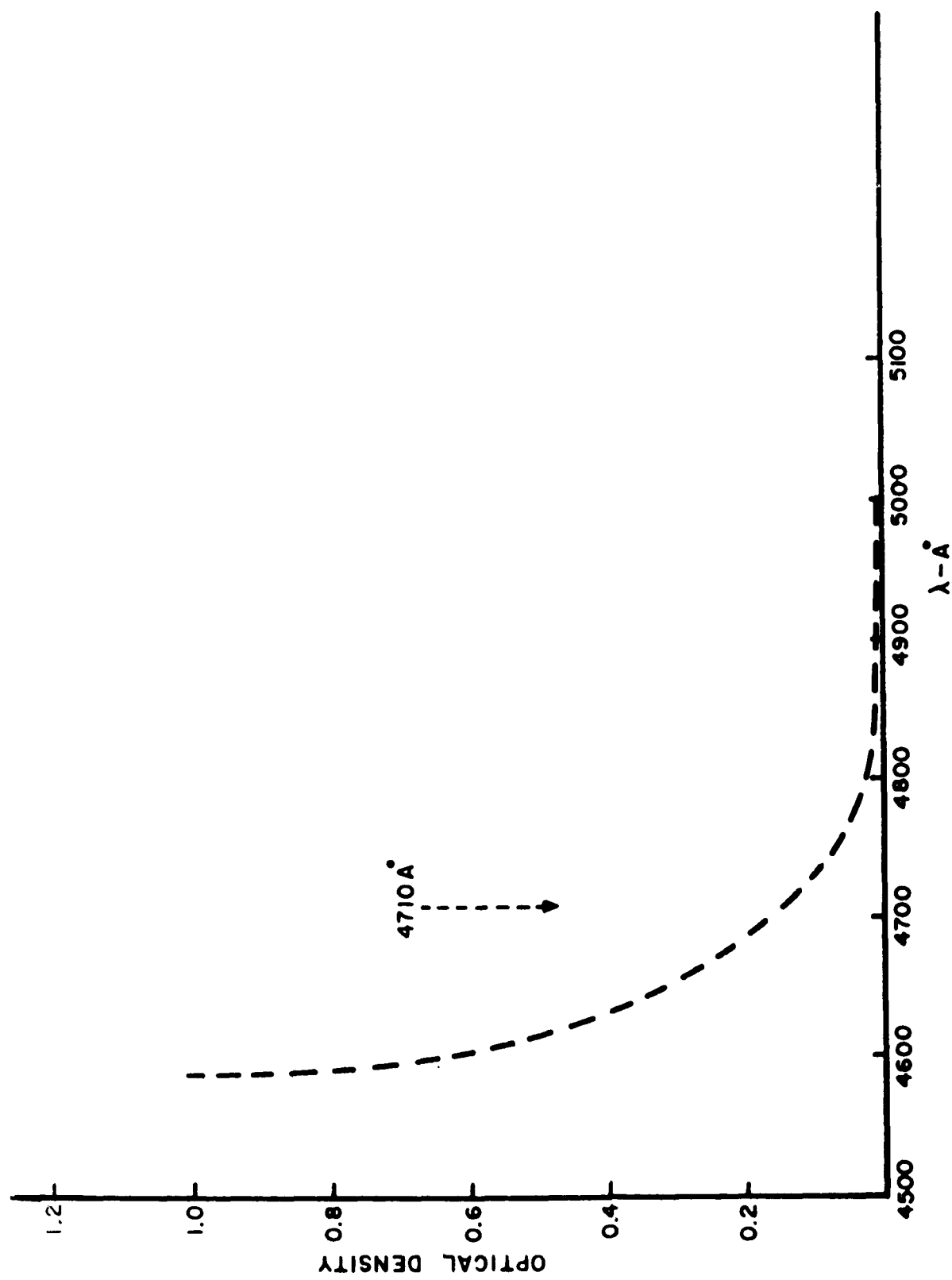
Figure 2 illustrates the experimentally obtained absorption of a 5.56×10^{-4} molar solution of perylene in benzene using a 10 cm cell. From the optical density at 4710 Å, we calculate that the terminal ground state separation is about 1300 cm^{-1} in fair agreement with the spectroscopic value. Due to the assumptions employed, no better agreement should be expected.

B. Polymerization Studies

In the previous report, it was shown that casting of the dye-monomer solution in the absence of oxygen produced the highest optical quality polymer rods. When the birefringence studies were begun, it was found necessary to add dibutyl phthalate (see Section C). the polymerization rates in the presence of the dibutyl phthalate were slowed down to the



ABSORPTION AND FLUORESCENCE SPECTRUM OF PERYLENE IN BENZENE
FIGURE 1



LONG WAVELENGTH ABSORPTION OF 5.56×10^{-4} MOLAR PERYLENE IN BENZENE (10cm PATH LENGTH)

FIGURE 2

extent that the organic dyes were oxidized by the catalyst, benzoyl peroxide. It was not found possible to adjust the rates of growth and concentration of catalyst used to prevent degradation of the dye. Part of the difficulty can be traced to the fact that the catalyzing agent is not completely used up at the end of the polymerization.

Another catalyst has been found which is used up completely, requires lower initial concentrations and does not oxidize the dye. This catalyst is α, α' -azodiisobutyronitrile. The appropriate samples have now been prepared for the stress optical measurements to be described below. The samples are grown in oxygen evacuated pyrex tubes under the temperature cycle given below;

40°C	2 days
Raise 40° to 60°C	1 day
Raise 60°C to 100°C	1 day
100°C	3 days
Cool and anneal at 102°C.	

C. Optical Properties of Polymers

It was noted in the last semiannual report that most polymers are birefringent in their natural state due to stresses which cannot be annealed out of the samples. If a high polymer is stressed there is a restoring force which originates from two types of molecular processes. One of these is an entropy component which is the result of the orientation produced by the deformation. Brownian motion of each segment of the distorted polymer chain operates to return the chain to its more probable configuration. The entropy force increases with temperature because of increased Brownian motion. There is also a potential energy component of the force which is a result of the attraction (or repulsion) between molecules that have been pulled apart (or squeezed together) during the deformation. Thermodynamically, the force, f , is

$$f = \left(\frac{\partial W}{\partial l} \right)_T = \left(\frac{\partial U}{\partial l} \right)_T - T \left(\frac{\partial S}{\partial l} \right)_T$$

For an ideal rubber, only the entropy contribution is present.

If a polymer is stretched and held at constant length, the stress relaxes as a result of a rearrangement of the chains from their initial deformed configuration to the more probable configuration. Chemical reactions, viscous flow, localized strain rearrangement and crystallization are some of the processes which can change the polymers' configuration.

High polymers typically exhibit two types of behavior. At, or near, room temperature, most of them are in a glassy state characterized by frozen chain orientations. For polymers in this state, the birefringence is proportional to the stress for small values of stress and the stress arises principally from the potential energy term described above. At higher temperatures, the polymer changes conformation to a rubbery state characterized by stresses arising almost from the purely entropy considerations. A more complete discussion of these effects can be found elsewhere⁽¹⁾.

The transition from the rubbery state to the glassy state is a second-order transition. Since all polymers of interest must be annealed in the rubbery state and cooled to a glassy state, and since it is not possible to maintain exact thermal equilibrium in passing through the transition temperature, it is not possible to remove all the stresses in a polymer sample. As a result, all polymers exhibit stress-induced birefringence, even after careful annealing.

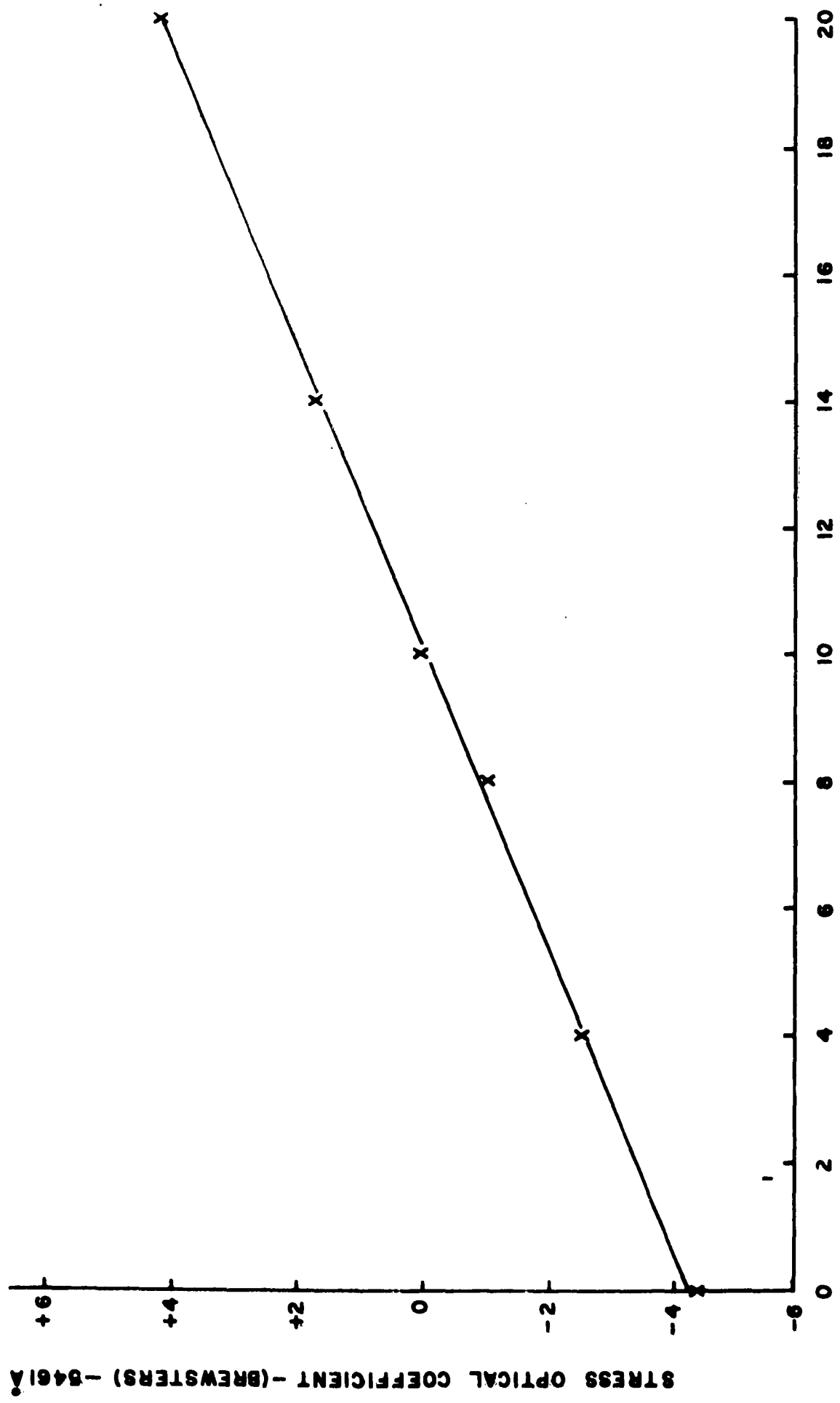
The birefringence is related to the stress by

$$\Delta N = KF$$

where K is the stress-optical coefficient and

F is the force per unit area.

Typical values of K for polymethyl methacrylate are $-4 \times 10^{-13} \text{ cm}^2/\text{dyne}$. It has been shown by Lamble and Dahmouch⁽²⁾ that it is possible to obtain a zero stress-optical coefficient in polymethyl methacrylate by the addition of dibutyl phthalate. Figure 3 shows a measured stress-optical coefficient



PERCENTAGE DIBUTYL PHTHALATE (BY WEIGHT)
FIGURE 3

for the modified polymer as a function of composition measured at 5461 Å. This was made on the benzoyl peroxide-catalyzed form of the undoped polymer. Due to the necessary changes in the polymerization of the polymer described in Section B, it will be necessary to re-determine the stress-optical coefficients for the polymers produced using the new catalyst system. The measurements will be made at 5461 Å and 4358 Å in order to ensure that differences in dispersion between the ordinary and extraordinary ray do not require a slight shift in composition. When this is done, it will be possible to produce a polymer which is optically isotropic and thus suitable for forming a proper resonant cavity.

III. DEVICE DEVELOPMENT

The development of a suitable optical pump involves generally a pulse of at most 1 microsecond duration, with a peak power of at least 100 megawatts without any sacrifice in terms of brightness of a lamp. It has become increasingly evident that black body systems such as the common xenon flash tube exhibit saturation of the lamp brightness at black body temperatures of 12-15,000°K⁽³⁾. Previous experiments with the generation of short pulses of 100-200 nanoseconds duration showed that the lamps did not increase in brightness appreciably with apparent increased peak power. The theta-pinch lamp work described by Feldman and coworkers⁽⁴⁻⁶⁾ is the subject of a current controversy⁽⁷⁾. However, it is a lamp which yields a pulse of short duration and whose brightness remains relatively high. During this report period, we have constructed such a lamp and have attempted to maximize the various operating parameters.

The lamp-capacitor system utilizes a 0.9 microfarad, 50 KV clam-shell capacitor (GE 14F756G2) in conjunction with a single turn coil surrounding a toroidal bottle containing argon at various pressures with an appropriate switch. The bottle is 1 1/8" OD, 5/16" ID, and 3" long. The fill gas pressures range from 1-100 millimeters.

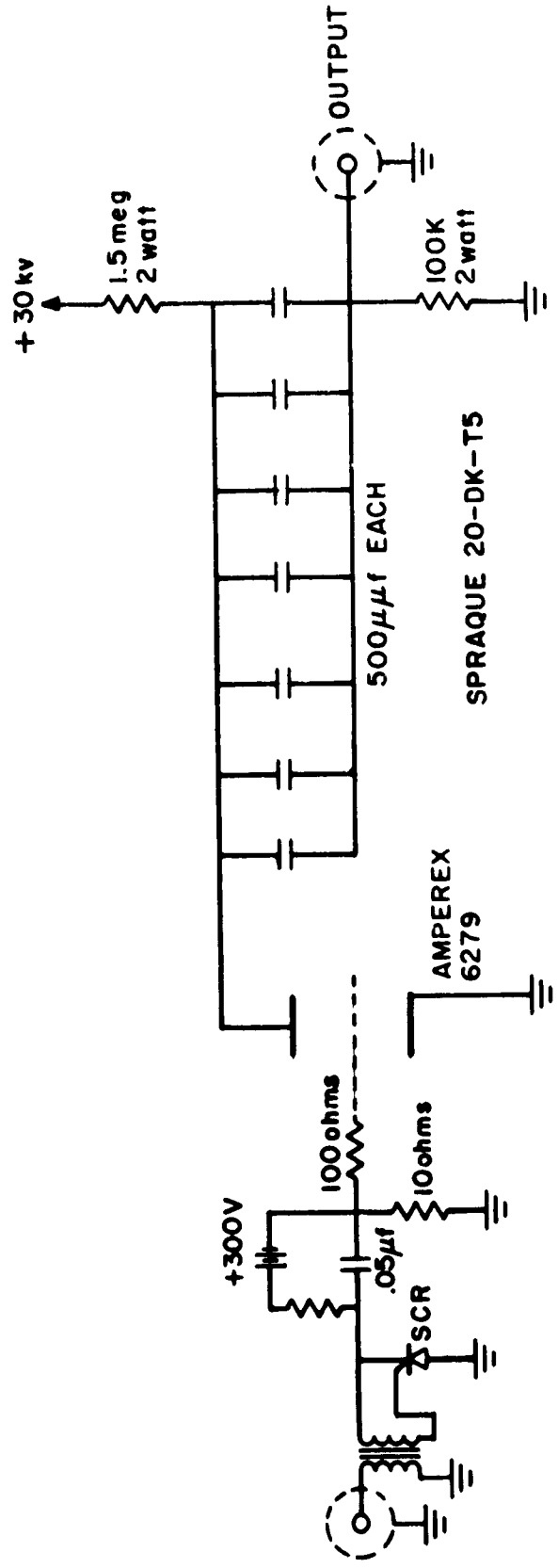
The chief experimental difficulty involves the switch. A number of switches have been tried. Initially, a high current ignitron was tried but the inductance (20 to 30 nanohenries) limited the current rise, so that inefficient operation and a rather long pulse of about 10 microseconds was attained. A simple airgap switch proved somewhat more satisfactory but at the higher voltages required, the gap separation was too large to switch the gap rapidly. Pulses of 4-5 microseconds were obtained. A switch of the Lupton design⁽⁸⁾ first made at NRL was constructed and it gave further improved performance. The switch now being tested is a pressurized version of the Lupton design manufactured by Cooke Engineering Company of Alexandria, Virginia (Model ME40-10,000).

It is capable of fast triggering at 50 KV without a wide gap separation. The characteristics of this gap are as follows:

maximum voltage	-	50 KV
peak current	-	10^6 amperes
total energy switched	-	10^4 joules
inductance	-	less than 10 nanohenries
dynamic impedance	-	5 milliohms

In the circuit we employ this should produce a pulse which rises in about 1.5×10^{-7} seconds and lasts about 1 microsecond depending on the coupling efficiency. The importance of rapid switching cannot be over-emphasized. In order to trigger the switch properly, a voltage pulse rising at the rate of 1 KV/nanosecond is required. Figure 4 shows the appropriate thyatron circuit which is wired in accordance with good high frequency practice.

The spectral characteristics of this lamp are important. Feldman's data⁽⁷⁾ is shown in Figure 5. The black spectrum is for an argon gas pressure of one millimeter and the white spectrum is at 20 millimeters gas pressure. At 20 millimeters, the continuum is obviously more significant. We plan to perform similar experiments at General Electric's Advanced Technology Laboratories using equipment developed under a previous flash lamp study contract (NONR-4121(00)). These experiments will be performed in order to measure the absolute brightness and efficiency of the source in addition to its time resolved spectroscopic characteristics.



SPARK GAP FIRING CIRCUIT
FIGURE 4

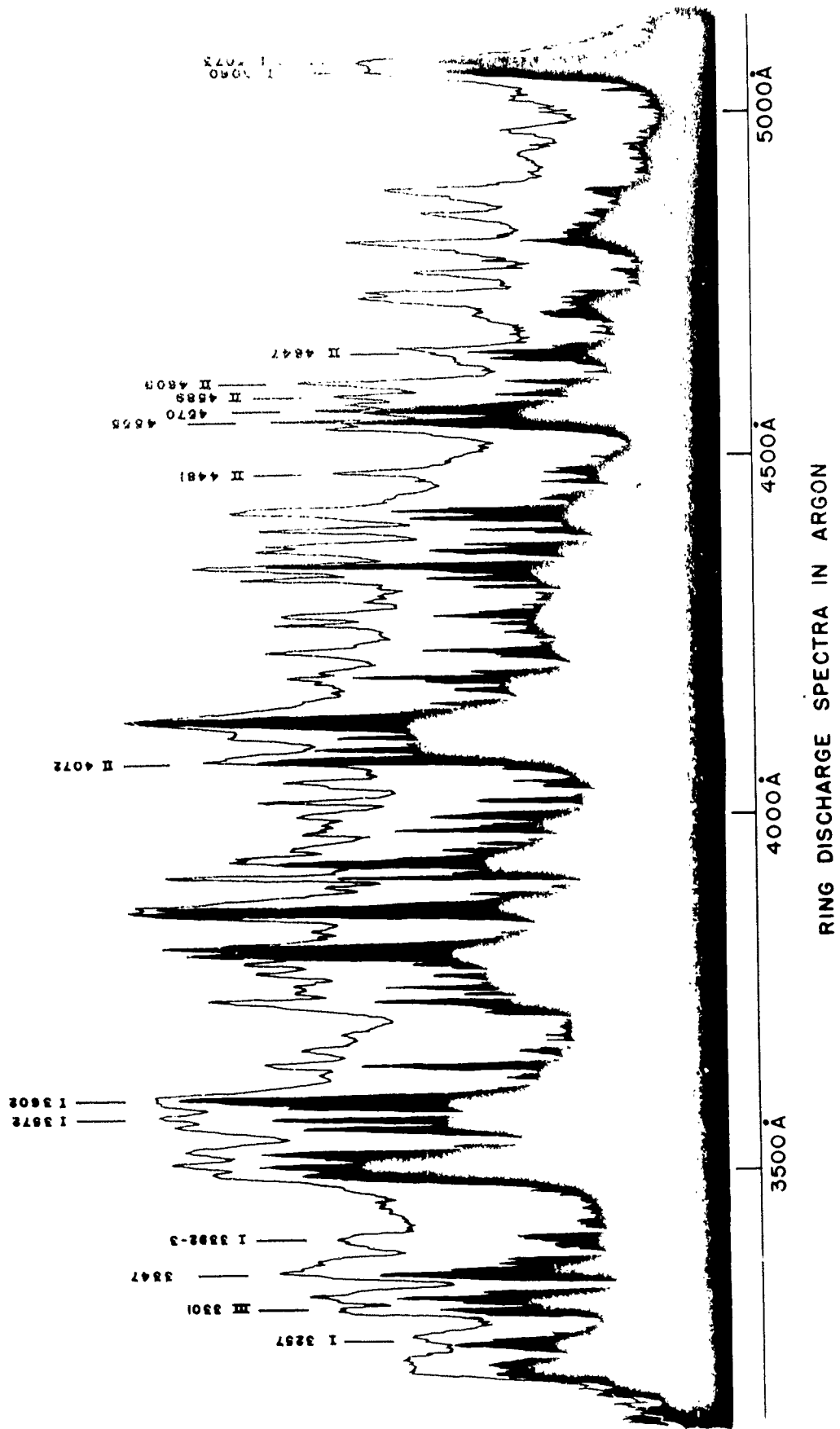


FIGURE 5

IV. BIBLIOGRAPHY

1. R.S. Stein, in Die Physik der Hohenpolzmeren, Vol. IV, by H.A. Stuart, p. 110, Springer-Verlag, Berlin, 1956.
2. J.H. Lamble and E.S. Dahmouch, Brit. J. Appl. Phys., 9, 388 (1958).
3. H.R. Koenig, Final Report, NONR 4121(00). for Office of Naval Research, 1964.
4. J.M. Feldman and J.S. Hitt, "Spectra of High Intensity Electrodeless Discharges in Rare Gases," American Physical Society Meeting, Edmonton, August 1963.
5. R.H. Brandewie, J.S. Hitt and J.M. Feldman, J. Appl. Phys., 34, 3415 (1963).
6. W.T. Haswell, J.S. Hitt and J.M. Feldman, IEEE, 52, 93 (1964).
7. Discussion in Laser Flashlamp Conference Proceedings, Sponsored by ONR and ARPA, at Stanford Research Institute, 20 Feb. 1964.
8. W.H. Lupton, Proc. Conf. Ionization Phen., in Gases, p. 2059, Munich, 1961.

REPORT DISTRIBUTION LIST

	<u>No. of Copies</u>
CA Black General Electric Company Advanced Technology Laboratory Schenectady, New York	1
S Byron Aeronutronic Division of Ford Motor Co. Ford Road Newport Beach, California	1
RS Congleton Hughes Aircraft Corp. Aerospace Group Research and Development Division Culver City, California	1
Basil Curnutte, Jr. Kansas State University Manhattan, Kansas	1
GH Dieke Johns Hopkins University Baltimore 18, Maryland	1
J Gerhauser North American Aviation, Inc. Los Angeles Division International Airport Los Angeles 9, California	1
James Hobart Laser Systems Center of Lear Seigler, Inc. 2320 Washtenaw Avenue Ann Arbor, Michigan	1
CH Keller Pek Labs, Inc. 925 Evelyn Avenue Sunnyvale, California	1
SP Keller International Business Machines TJ Watson Research Center Yorktown Heights, New York	1

	<u>No. of Copies</u>
CG Kirkpatrick Autonetics Division of North American Aviation Anaheim, California	1
A Lempicki General Telephone and Electronics Labs. Bayside 60, New York	1
TH Maiman Korad Corporation 2520 Colorado Avenue Santa Monica, California	1
Joseph I. Masters Technical Operations Research Burlington, Massachusetts	1
TE McAvoy Corning Glass Works Corning, New York	1
W. McKusick Eastman Kodak Company Apparatus and Optical Division 400 Plymouth Avenue, N. Rochester 4, New York	1
JF Miller Battelle Memorial Institute 505 King Avenue Columbus 1, Ohio	1
OH Nestor Linde Company 1500 Polco Street Indianapolis 24, Indiana	1
JW Nielson Airtron, A Division of Litton Industries 200 East Hanover Avenue Morris Plains, New Jersey	1
Gerald Oster Chemistry Department Polytechnic Institute of Brooklyn 333 Jay Street Brooklyn 1, New York	1

	<u>No. of Copies</u>
RG Seed Northeastern University Boston, Massachusetts	1
JW Turner Westinghouse Electric Corp. Electronics Division P.O. Box 1897 Baltimore 3, Maryland	1
HA Weakliem Radio Corporation of America David Sarnoff Research Center Princeton, New Jersey	1
CG Young American Optical Company Southbridge, Massachusetts	1
WP Siegmund American Optical Company Southbridge, Massachusetts	1
Dr. Jerald R. Izatt New Mexico State University University Park, New Mexico	1
Professor AK Kamal Purdue University School of Electrical Engineering Lafayette, Indiana	1
Mr. Thomas C. Marshall Columbia University Dept. of Electrical Engineering New York 27, New York	1
Mr. Charles G. Naiman Mithras, Inc. Cambridge 39, Massachusetts	1
Dr. JH Schulman Solid State Division US Naval Research Laboratory Washington 25, D.C.	1
Dr. Jack A. Soules Physics Department New Mexico State University University Park, New Mexico	1

	<u>No. of Copies</u>
Dr. Arden Sher Varian Associates 611 Hansen Way Palo Alto, California	1
Physical Sciences Division: Army Research Office Office, Chief, Research and Development Washington 25, D.C. ATTN: Dr. Robert A. Watson	1
Chief Scientist US Army Electronics Command Fort Monmouth, New Jersey ATTN: Dr. Hans K. Ziegler	1
Director, Institute for Exploratory Research Army Signal Research and Development Laboratory Fort Monmouth, New Jersey ATTN: Dr. EM Reilley	1
Asst. Director of Surveillance Army Signal Research and Development Laboratory Fort Monmouth, New Jersey ATTN: Dr. Harrison J. Merrill	1
Director, Technical Ballistics Laboratory Ballistics Research Laboratory Aberdeen Proving Ground Aberdeen, Maryland ATTN: Dr. Edwin Minor	1
Director of Research and Development Army Ordnance Missile Command Huntsville, Alabama ATTN: Mr. William D. McKnight	1
Office, Chief of Naval Operations /OP-07T-1/ Department of the Navy Washington 25, D.C. ATTN: Mr. Ben Rosenberg	1
Bureau of Naval Weapons /RR-2/ Department of the Navy Washington 25, D.C. ATTN: Dr. CH Harry	1
Bureau of Ships /CODE 305/ Department of the Navy Washington 25, D.C. ATTN: Dr. GC Sponsler	1

	<u>No. of Copies</u>
Office of Naval Research /CODE 402C/ Department of the Navy Washington 25, D.C. ATTN: Dr. Sidney Reed	1
Office of Naval Research /CODE 421/ Department of the Navy Washington 25, D.C. ATTN: Mr. Frank B. Isakson	3
Office of Naval Research /CODE 406T/ Department of the Navy Washington 25, D.C. ATTN: Mr. JW Smith	1
Naval Research Laboratory /CODE 6440/ Department of the Navy Washington 25, D.C. ATTN: Dr. CC Klick	1
Naval Research Laboratory /CODE 7360/ Department of the Navy Washington 25, D.C. ATTN: Dr. LF Drummeter	1
Headquarters USAF /AFRDR-NU-3/ Department of the Air Force Washington, D.C. ATTN: Lt Col EN Myers	1
Research and Technology Division Bolling AFB Washington, D.C. ATTN: Mr. Rober Feik	1
Office, Aerospace Research /MROSP/ Washington 25, D.C. ATTN: Lt Col Ivan Atkinson	1
Technical Area Manager /760A/ Advanced Weapons Aeronautical Systems Div. Wright-Patterson AFB Ohio ATTN: Mr. Don Newman	1
Project Engineer /5237/ Aerospace Radiation Weapons Aeronautical Systems Division Wright-Patterson AFB Ohio ATTN: Mr. Don Lewis	1

	<u>No. of Copies</u>
Air Force Special Weapons Center /SWRPA/ Kirtland AFB New Mexico ATTN: Capt. Marvin Atkins	1
Project Engineer /5561/ COMET Rome Air Development Center Griffiss AFB New York ATTN: Mr. Phillip Sandler	1
Department of Electrical Engineering New York University University Heights New York, New York ATTN: Mr. Thomas Henion	1
BMDR Room 2 B 263 The Pentagon Washington 25, D.C. ATTN: Lt Col WB Lindsay	8
Joint Advance Study Group Joint Chiefs of Staff Room 2 C 825 The Pentagon Washington 25, D.C. ATTN: Col. CA Barninger	1
Mr. JP Chernoch General Electric Laboratory Schenectady, New York	1
JW Eerkens Terra Nova MHD Research, Inc. Post Office Box 1815 Newport Beach, California	1
Mr. John Emmett Physics Department Stanford University Palo Alto, California	1
Dr. Harry Heard Radiation at Stanford 3180 Hanover Street Palo Alto, California	1

	<u>No. of Copies</u>
Secretary, Special Group on Optical Masers ODDRCE Advisory Group on Electron Devices 346 Broadway - 8th Floor New York 13, New York	3
ASD /ASRCE-31/ Wright-Patterson AFB, Ohio	1
Dr. Rubin Bronstein Radio Corporation of America David Sarnoff Research Center Princeton, New Jersey	1
Dr. W Holloway Sperry Rand Research Center Sudbury, Massachusetts	1
Technical Area Manager /760B/ Surveillance Electronic Systems Division LG Hanscom AFB Massachusetts ATTN: Major HI Jones, Jr.	1
Commanding Officer US Naval Ordnance Laboratory Corona, California	1
Director US Army Engineering Research and Development Laboratories Fort Belvoir, Virginia ATTN: Technical Documents Center	1
Office of the Director of Defense Defense Research and Engineering Information Office Library Branch Pentagon Building Washington 25, D.C.	2
US Army Research Office Box CM, Duke Station Durham, North Carolina	2
Defense Documentation Center Cameron Station Building Alexandria 14, Virginia	20
Director US Naval Research Laboratory Technical Information Officer CODE 2000, CODE 2021 Washington 25, D.C.	6

	<u>No. of Copies</u>
Commanding Officer Office of Naval Research Branch Office 230 N. Michigan Avenue Chicago, Illinois	1
Commanding Officer Office of Naval Research Branch Office 207 W. 24th St. New York 11, New York	1
Commanding Officer Office of Naval Research Branch Office 1000 Geary Street San Francisco 9, California	1
Air Force Office of Scientific Research Washington 25, D.C.	1
Director National Bureau of Standards Washington 25, D.C.	1
Director Research Department US Naval Ordnance Laboratory White Oak, Silver Springs, Md.	1
Commanding Officer Office of Naval Research Branch Office 1030 East Green Street Pasadena 1, California	1
Commanding Officer Office of Naval Research Branch Office 495 Summer Street Boston 10, Mass.	1
US Naval Radiological Defense Laboratory /CODE 941/ San Francisco, California 94135	1
Commanding Officer US Army Materials Research Agency ATTN: Technical Library Watertown, Massachusetts 02172	1
Boulder Laboratories National Bureau of Standards ATTN: Library Boulder, Colorado	1

	<u>No. of Copies</u>
Chief, Bureau of Ships CODE 340 Department of the Navy Washington 25, D.C.	1
Chief, Bureau of Ships CODE 360 Department of the Navy Washington 25, D.C.	1
Chief, Bureau of Ships CODE 370 Department of the Navy Washington 25, D.C.	1
Air Force Weapons Laboratory ATTN: Guenther WLRPF Kirtland Air Force Base New Mexico	1
Chief, Bureau of Naval Weapons Department of the Navy Washington 25, D.C. ATTN: JM Lee RMGA-81	1
Air Force Cambridge Research Laboratories ATTN: CRXL-R, Research Library Lawrence G. Hanscom Field Bedford, Massachusetts	1
Battelle Memorial Institute 505 King Avenue Columbus 1, Ohio ATTN: BMI-Defender	1